STEREO-FIBERSCOPIC MEASUREMENT OF THE LARYNX: A PRELIMINARY EXPERIMENT BY USE OF ORDINARY LARYNGEAL FIBERSCOPES

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Direct observation of laryngeal action by use of a fiberoptics system has provided new scope in the study of the speech production mechanism.[1)-4)] One of the limitations in this technique is that there is no reference available for measuring absolute dimensions of the laryngeal image, such as the real size of the glottal aperture. This paper reports on a preliminary study of measuring the absolute dimensions of the larynx by use of a stereoscopic technique.

Instrumentation and Principle of Stereoscopic Measurement

Two fiberscopes of the same type, ordinary laryngeal fiberscopes with an outside diameter of 4.5 mm, were utilized in this experiment. The optical system of the fiberscope is designed to provide a square field of view. The tips of the two fiberscopes were placed in a special stereo-appliance so that the distance between the optical axes of the two fiberscopes at their tips was fixed at 6.6 mm (Fig. 1). The alignment of the two

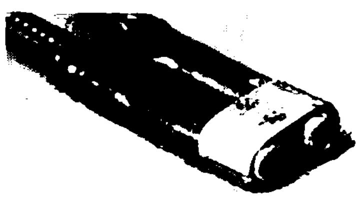

Fig. 1: Laryngeal fiberscopes placed in the stereo-appliance

fiberscopes and the principle of the stereoscopic measurement are illustrated in Fig. 2 AB. As seen in the figure, the view fields covered by the two fiberscopes differ from each other to a certain extent on a plane of observation X. Consequently, there is a relative shift in the location of a given point R (reference point) on the plane X when we compare the two view fields. The value of the relative shift in the image field (b in Fig. 2B) corresponds to the distance between the two optical axes on the plane X, which is given by "$r-2L\tan\alpha$". The length S of the side of the square view field corresponds to "$2L\tan\theta$".

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If σ is a ratio of b to S,

$$(1)\ \sigma = \frac{b}{S} = \frac{r-2L\tan\alpha}{2L\tan\theta}$$

then the distance (L) is calculated by

$$(2)\ L = \frac{r}{2\sigma\tan\theta + 2\tan\alpha}$$

The length (m) in the image field (Fig. 2 B) corresponds to (W) in the plane (X). Thus:

$$(3)\ W = \frac{m}{S} 2L\tan\theta$$

Procedure and Calibration of the Measurement

A computer-aided measurement of the film frames was employed here. The outline of the procedure has already been described in a previous issue of the Annual Bulletin by Miyazaki et al [5].

On the scope display of the computer where the film image through one of the fiberscopes is projected, we first determine the frame of the square image field in order to obtain S in Fig. 2B and also the coordinate of the center of the image field, i. e. the optical axis. Then coordinates of the reference point R and those of point of measurement for (m) in Fig. 2 B are determined.

The value θ in Fig. 2A is a constant to be specified for each fiberscope. Then values of the distance L and the length W are calculated by equations (1) - (3) when the value α is given.

In our present system using ordinary laryngeal fiberscopes, there is some difficulty in predetermining the value α, i. e. the angle formed by the two optical axes. Because of the round and tapered hard tip with a soft cover reaching to nearly the end of the tip, the angle α changes, though slightly, when the scopes are removed from the appliance and then repositioned again. Furthermore, square image frames of the two fiberscopes are not actually aligned in parallel to each other but are rotated to some extent. This rotation also causes a relative shift in the locations of the reference point between the two image fields.

These problems should be solved by improving the structure of the stereo-appliance and the tip of the fiberscope if we design a special fiberscope for stereoscopic use. In the present study, a calibration pattern was photographed stereoscopically in order to estimate the angle α and the rotation of the image fields before and after each experimental session.

The accuracy of the measurement is considered to be limited by several factors such as the image resolution of the fiberscope and human error in determining the point of measurement. The error of the measurement was estimated by photographing the calibration pattern at varying distances. The results are plotted in Fib. 3 where the abscissa indicates the real value of the distance and the ordinate the error in the stereoscopic measurement of the distance. As seen in the figure, the range of error increased with increasing distance, and the maximum error rate at the

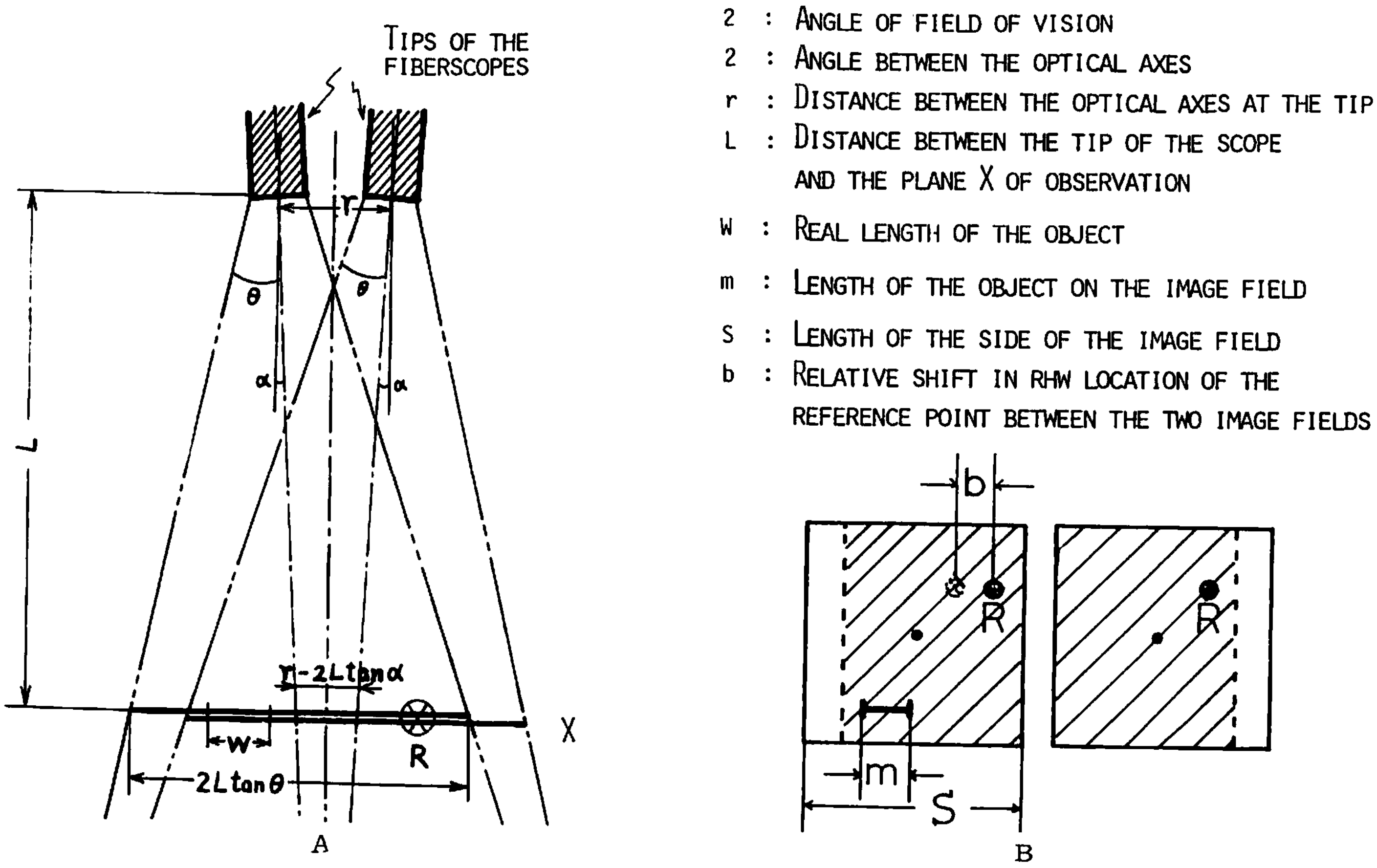

Fig. 2: Principle of stereoscopic measurement.

distance of 55 mm was approximately 10%.

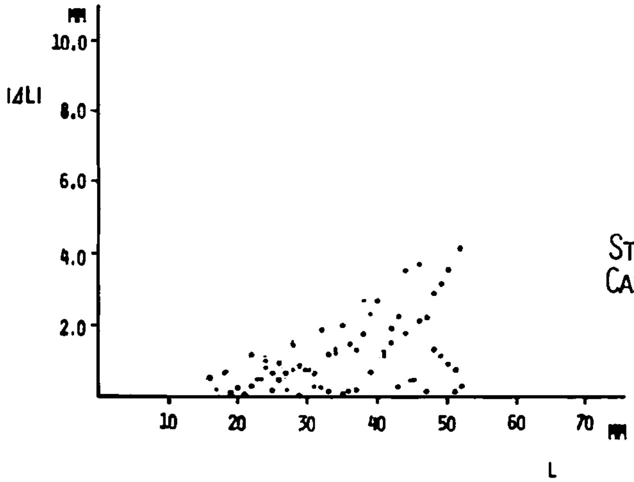

Fig. 3: Error of the measurement.

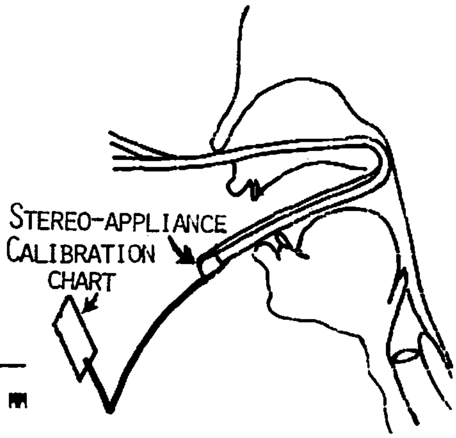

Fig. 4: Calibration before and after the laryngeal observation.

Measurement of the Larynx

Two fiberscopes are inserted separately through the left and right nostrils of the subject and pulled out from the mouth. The fiberscopes are then put together by the stereo-appliance and the calibration pattern is photographed at several different distances (Fig. 4). The tips of the fiberscopes are again pushed into the pharynx for observation of the larynx. In the present experiment, the glottal view was recorded in 16 mm cine films at a frame rate of 24 per second using cine cameras attached separately to each of the fiberscopes. Timing marks were simultaneously recorded for synchronizing two cine films and speech signals.

Figure 5 shows the result of the stereoscopic measurement on the distance between the tip of the fiberscope and the valeculla epiglottica during repeated phonation of sustained [e]. In the figure, the ordinate indicates the distance (10 mm for each division) and the abscissa the number of film frames (10 frames for each division). The distance measured for each film frame was plotted in the graph. The average distance during phonation was 33.9 mm and that during voicing gap was 30.7 mm. The reference point in this measurement was a particular contour of the blood vessels of the valeculla.

Figure 6 is the result of measurement during quiet respiration. The reference point here was the anterior commissure of the glottis. In the upper plot of the graph, the distance between the tip of the fiberscope and the glottis is shown to be 51. 9 mm on the average. In the lower part of the graph, the size of the glottal aperture, i. e. the distance between the vocal processes, was plotted. The size of the glottal aperture varies to a considerable extent, in relation to inspiratory and expiratory actions.

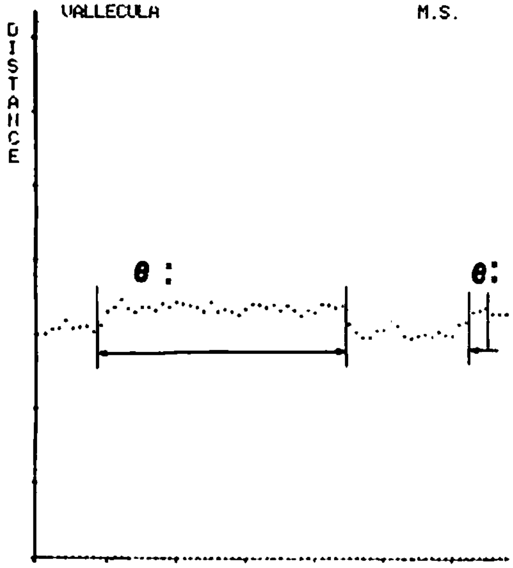

Fig. 5: Distance between the scope and the valeculla epiglottica during repeated phonations of sustained /e/.

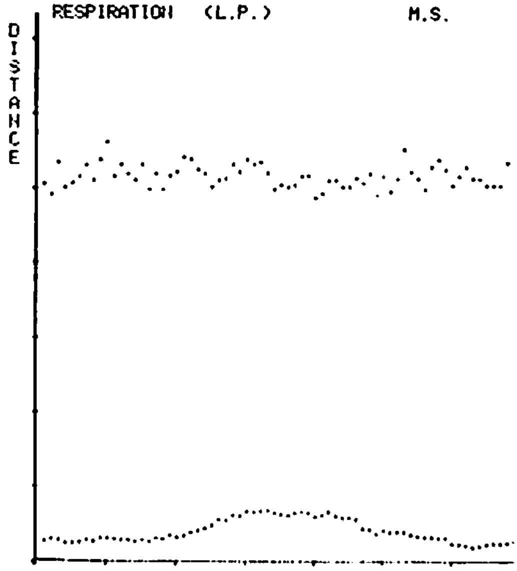

Fig. 6: Distance between the scope and the glottis (upper plots), and the glottal opening (lower plots) during quiet respiration.

RESPIRATION	BLOWING	SPEECH
MM	MM	MM
exp. 2.0 - 3.0	2.5 - 3.0	[ss] 2.0 - 3.0
ins. 4.0 - 6.0	7.0 - 8.0	[kk] 1.7 - 2.4
		[tt] 1.0 - 1.5

Tab. 1: Values of the glottal aperture for different laryngeal gestures.

Table 1 shows the distance between the vocal processes in respiration, blowing, and speech articulation. In speech, isolated utterances of test words, [sesse:], [sekke:], and [sette:] were examined. The glottal opening in quiet respiration decreased during expiration to the minimum value of 2.0 - 3.0 mm and increased during inspiration reaching the value of 4.0 - 6.0 mm. The glottal aperture during blowing is comparable with that of quiet expiration while it increased to 7.0 - 8.0 mm during quick (or forced) inspiration following the blowing. The glottis for geminate [s] is comparable to that of quiet expiration while it is smaller for geminate stops.

References

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